HMD-Based Navigation for Ventriculostomy

Group 15 Project Proposal

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Content:

1. Project Goal

This project is aimed to introduce image guidance via augmented reality on HoloLens. The image guidance is AR overlay of ventricle model from CT image and catheter guide overlay.

2. Background

A ventriculostomy is a device that drains excess cerebrospinal fluid from the head. It is also used to measure the pressure in the head (referred to as ICP, intracranial pressure). The system is made up of a small tube, drainage bag, and monitor. Here is a brief surgical procedure for ventriculostomy refer to **Figure 1** below:

1. Incision
2. Hole burred into bone to create opening for catheter
3. Insert catheter and drain excess fluid from ventricle

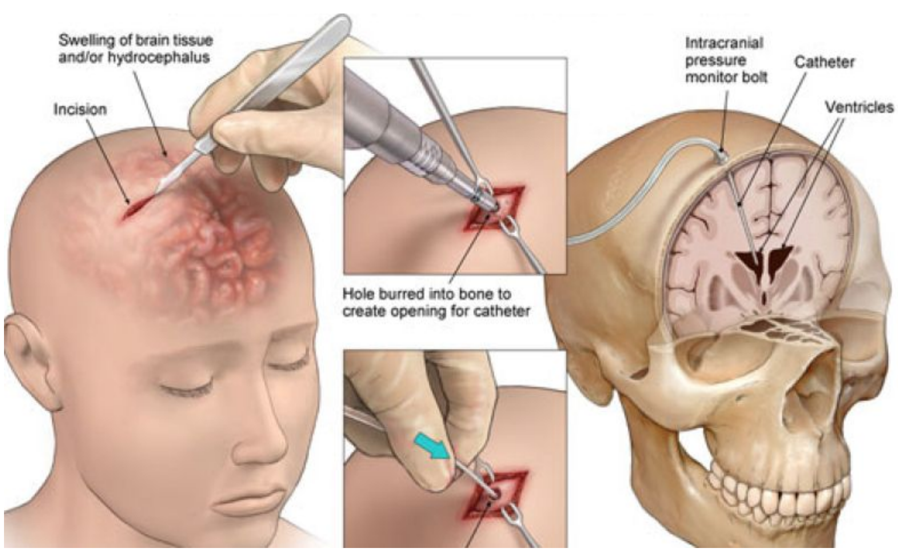

Figure 1: Ventriculostomy Procedure

Photo credit: http://www.medicalexhibits.com/medical_exhibits_image.php?exhibit=07066_03X

3. Motivation

According to the article “optimization of ventricular catheter placement via posterior approaches: a virtual reality simulation study”, although ventricular shunt surgery being a common procedure and parieto-occipital approach being the favored approach, the accuracy of catheter placement is only 33%. It is mainly due to the fact that catheter placement is rely on surgeon's experience and anatomy. In fact, surgeon has to guess the location of ventricle from CT image and anatomic points such as glabella and temple. **Figure 2** shows that how catheter is placed in ventricle based on anatomy. Thus, it makes our project remarkable for increasing the catheter placement accuracy.

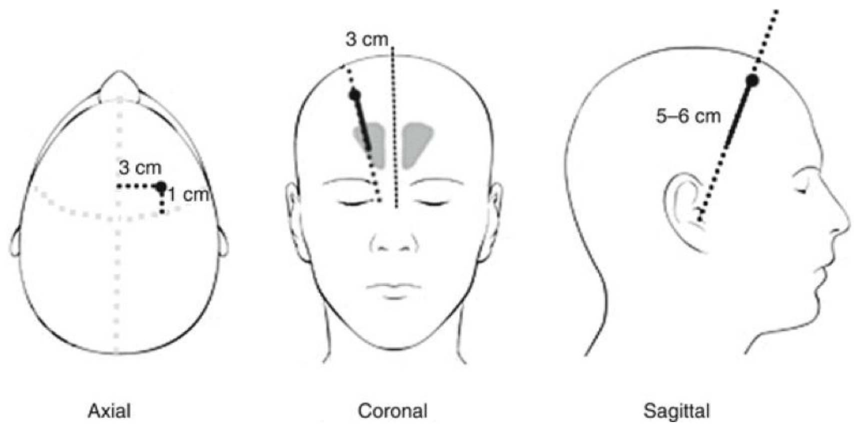

Figure 2: Catheter Placement in Ventriculostomy

Photo Credit: Shahlaie K., Muizelaar J.P. (2012) Ventriculostomy. In: Vincent JL., Hall J.B. (eds) Encyclopedia of Intensive Care Medicine. Springer, Berlin, Heidelberg

4. Technical Approach

Our navigation system work flow diagram is shown as **Fig. 3**, and the following steps describes the workflow in detail.

a. A ZED mini camera mounted to HoloLens to track skull(AR marker) and catheter
b. Register CT to patient by touching anatomic points (glabella)
c. Create ventricle model by segmenting CT on PC and import model to Unity
d. Unity generate AR overlay of ventricle and overlay via HoloLens
    i. Target accuracy within 3 mm
e. Unity generate entry point by touching and overlay via HoloLens
f. Display Catheter guide line on HoloLens, which a virtual line from centroid of ventricle to entry point with possibility for entry point adjustment
g. Catheter tracking result including catheter insertion depth, angle that processed on PC and send to Unity through UDP
h. Unity receive catheter tracking result from PC and overlay the information via HoloLens

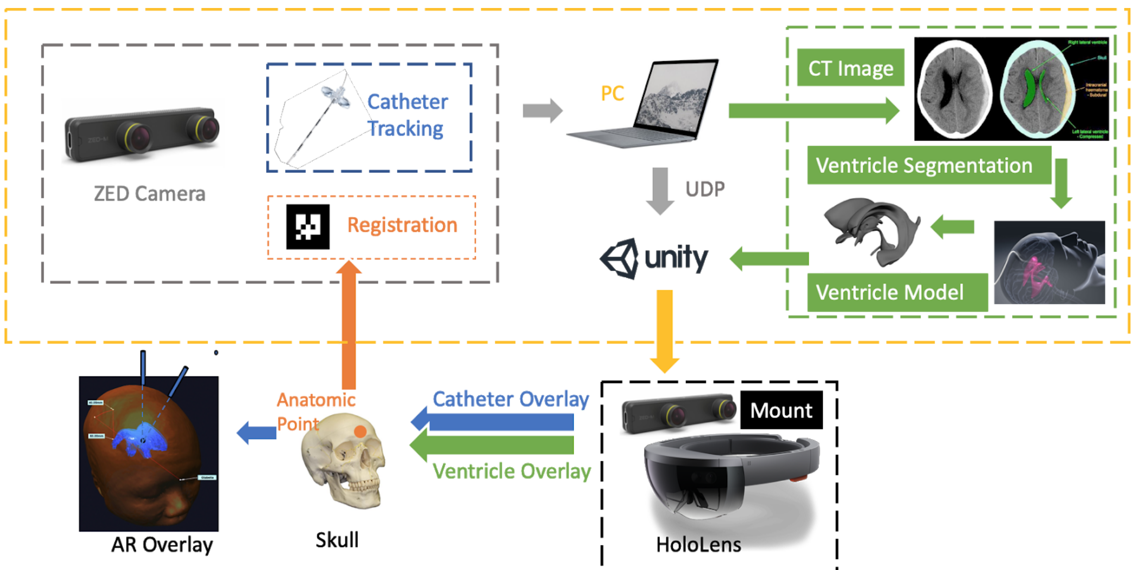

Figure 3: Workflow Chart

To evaluate our system performance, the accuracy test method is designed. We plan to 3D print a skull model with several small holes on the surface and a solid ventricle in it. Around the “ventricle” we will put a paper grid, while each region has corresponding score. Users will be ask to hit the ventricle using a catheter through these holes. For control group, users will try to finish this task without our navigation system, however they can still refer CT images to speculate the location of the ventricle. For experiment group, users will complete the task with the aid of our navigation system. Every user can only choose one hole and perform the task once. The percentage of successful hits and the average scores will be recorded for each group.

5. Deliverables

Minimum: Documentation and Code for Navigation System 1.0 includes

- Anatomic points registration by AR Marker
- AR overlay system indicating ventricle centroid and catheter entry based on anatomic points
- Report of accuracy test

Expected: Documentation and Code for Navigation System 2.0 includes

- Tool tracking system by touching anatomic points
- Camera system integrated to HoloLens
- Semi-automatic ventricle segmentation program
- Report of accuracy test

Maximum: Documentation and Code for Navigation System 3.0 includes

- Fully-automatic ventricle segmentation program
- Catheter tracking system with guidance of insertion error and insertion depth

6. Dependencies

Table 1 is our project dependencies which includes their solutions and current status. In the Status column, Green meas solved, and Red means planed.

Dependency	Solution	Status
Access to SMARTS Lab	Need Prof. Kazanzides sign the form	Resolved
Access to software: Unity, (HoloLens)ARToolKit, Vuforia, and HoloLens Emulator	Download from official websites	Resolved
Microsoft HoloLens	Ehsan will share his HoloLens with us	Resolved
AR Tags	Download from Internet and print them	Resolved
CT Data	Get from MIA course material	Resolved
Prior Work Code	Download from 2018 Spring CIS2 website	Resolved
Access to 3D Printer	Use LCSR 3D Printer	Due Mar. 8
Skull Model	3D print a skull model with a solid ventricle in it	Due Mar. 12
ZED Camera	Order from Internet	Due Mar. 14

Table 1: Project Dependencies

7. Schedule

Table 1 shows the detailed breakdown of schedule for each planned event for the project.

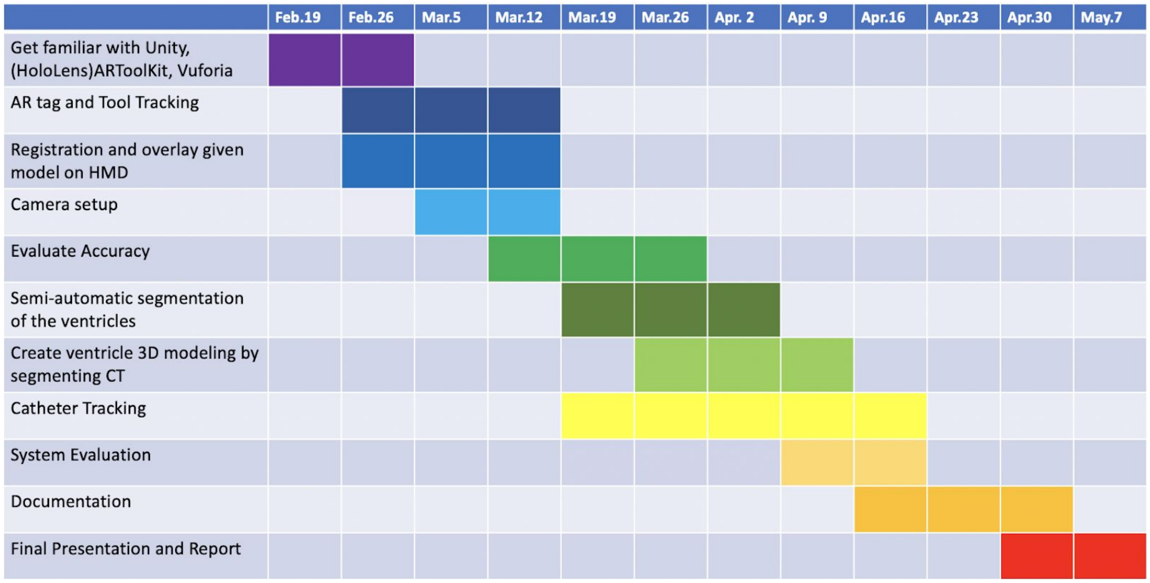

Table 1: Project Schedule

8. Milestones

- ➢ Mar 8th: Complete Navigation System 1.0 and project proposal
- ➢ Mar 26th: Evaluate and document Navigation System 1.0 written
- ➢ April 9st: Complete and document Navigation System 2.0
- ➢ April 25th Complete Navigation System 3.0
- ➢ May 1st: Documentation and Poster

9. Manage Plan

As a team, we plan to meet twice a week, on each Monday and Friday afternoon, in order to integrate each part we've done separately and run tests together. We will also have weekly meetings with Prof. Kazanzides and Ehsan on Wednesday 3 pm or by appointment. Minyi will mainly work on CT segmentation, ventricle modeling and camera setup, Yiwei will focus on building UI, AR tracking and AR overlaying. We will use a private Github repository, JH Box and course Wiki page to manage our code, data, and documentation.

10. Reading List

1. Azimi, E., et al.: Can mixed-reality improve the training of medical procedures? In: IEEE Engineering in Medicine and Biology Conference (EMBC), pp. 112–116, July 2018
2. Chen, L., Day, T., Tang, W., John, N.W.: Recent developments and future challenges in medical mixed reality. In: IEEE International Symposium on Mixed and Augmented Reality (ISMAR), pp. 123–135 (2017)
3. Azimi, E., Doswell, J., Kazanzides, P.: Augmented reality goggles with an integrated tracking system for navigation in neurosurgery. In: Virtual Reality Short Papers and Posters (VRW), pp. 123–124. IEEE (2012)
4. Qian, L., Azimi, E., Kazanzides, P., Navab, N.: Comprehensive tracker based display calibration for holographic optical see-through head-mounted display. arXiv preprint arXiv:1703.05834 (2017)
5. Sadda, P., Azimi, E., Jallo, G., Doswell, J., Kazanzides, P.: Surgical navigation with a head-mounted tracking system and display. Stud. Health Technol. Inform. 184, 363–369 (2012)
6. Sauer, F., Khamene, A., Bascle, B., Rubino, G.J.: A head-mounted display system for augmented reality image guidance: towards clinical evaluation for imri-guided nuerosurgery. In: Niessen, W.J., Viergever, M.A. (eds.) MICCAI 2001. LNCS, vol. 2208, pp. 707–716. Springer, Heidelberg (2001).
7. Azimi, Ehsan, et al.: Interactive Training and Operation Ecosystem for Surgical Tasks in Mixed Reality. *OR 2.0 Context-Aware Operating Theaters, Computer Assisted Robotic Endoscopy, Clinical Image-Based Procedures, and Skin Image Analysis*. Springer, Cham, 20-29.(2018).